

Claims

What is claimed is:

1. An accelerometer, comprising:
 2. a measurement mass for detecting acceleration, including:
 3. a housing having a cavity;
 4. one or more spring mass assemblies positioned within the cavity,
 5. each spring mass assembly including:
 6. a support structure;
 7. one or more resilient folded beams coupled to the support
 8. structure; and
 9. a mass coupled to the resilient folded beams; and
 10. one or more electrode patterns coupled to the spring mass
 11. assembly;
 12. a top cap wafer coupled to the measurement mass, including a top
 13. capacitor electrode; and
 14. a bottom cap wafer coupled to the measurement mass, including a bottom
 15. capacitor electrode.
 1. 2. The accelerometer of claim 1, wherein one or more of the spring mass assemblies further include:
 3. one or more range-of-motion stops coupled to the support structure for
 4. limiting the movement of the mass in the direction of the stops.
 1. 3. The accelerometer of claim 2, wherein one or more of the range-of-motion stops include one or more perforations for minimizing fluid damping.
 1. 4. The accelerometer of claim 2, wherein one or more of the range-of-motion stops are coupled to the side walls of the support structure.

- 1 5. The accelerometer of claim 2, wherein one or more of the range-of-motion stops
2 are coupled to the interior corners of the support structure.
- 1 6. The accelerometer of claim 1, wherein one or more of the resilient folded beams
2 include:
3 one or more range-of-motion limit stops for limiting movement of the
4 mass in the direction of the stops.
- 1 7. The accelerometer of claim 1, wherein one or more of the folded beams further
2 include:
3 a mass for dampening out resonances of the resilient folded beam.
- 1 8. The accelerometer of claim 1, wherein one or more of the spring mass assemblies
2 further include:
3 one or more soft range-of-motion limit stops for compliantly limiting
4 movement of the mass in the direction of the stops.
- 1 9. The accelerometer of claim 1, wherein one or more of the spring assemblies
2 further include:
3 corner tethers for coupling the corners of the mass to the opposing interior
4 corners of the support structure.
- 1 10. The accelerometer of claim 1, wherein one or more of the resilient folded beams
2 further include one or more cutouts for minimizing stress concentrations.
- 1 11. The accelerometer of claim 1, wherein one or more of the resilient folded beams
2 further include one or more cutouts for minimizing webbing formation during the
3 manufacture of the folded beams.
- 1 12. The accelerometer of claim 1, wherein one or more of the resilient folded beams
2 further include a webbing artifact having a hole for preventing the propagation of

3 cracks into the resilient folded beams.

- 1 13. An accelerometer, comprising:
2 a measurement mass for detecting acceleration, including:
3 a housing having a cavity;
4 one or more spring mass assemblies positioned within the cavity,
5 each spring mass assembly including:
6 a support structure;
7 one or more resilient S-shaped beams coupled to the
8 support structure; and
9 a mass coupled to the resilient S-shaped beams; and
10 one or more electrode patterns coupled to the spring mass
11 assembly;
12 a top cap wafer coupled to the measurement mass, including a top
13 capacitor electrode; and
14 a bottom cap wafer coupled to the measurement mass, including a bottom
15 capacitor electrode.
- 1 14. The accelerometer of claim 13, wherein one or more of the spring mass
2 assemblies further include:
3 one or more range-of-motion stops coupled to the support structure for
4 limiting the movement of the mass in the direction of the stops.
- 1 15. The accelerometer of claim 14, wherein one or more of the range-of-motion stops
2 include one or more perforations for minimizing fluid damping.
- 1 16. The accelerometer of claim 14, wherein one or more of the range-of-motion stops
2 are coupled to the side walls of the support structure.
- 1 17. The accelerometer of claim 14, wherein one or more of the range-of-motion stops
2 are coupled to the interior corners of the support structure.

- 1 18. The accelerometer of claim 13, wherein one or more of the S-shaped beams
2 include:
3 one or more range-of-motion limit stops for limiting movement of the
4 mass in the direction of the stops.
- 1 19. The accelerometer of claim 13, wherein one or more of the S-shaped beams
2 further include:
3 a mass for dampening out resonances of the resilient folded beam.
- 1 20. The accelerometer of claim 13, wherein one or more of the spring mass
2 assemblies further include:
3 one or more soft range-of-motion limit stops for compliantly limiting
4 movement of the mass in the direction of the stops.
- 1 21. The accelerometer of claim 13, wherein one or more of the spring assemblies
2 further include:
3 corner tethers for coupling the corners of the mass to the opposing interior
4 corners of the support structure.
- 1 22. The accelerometer of claim 13, wherein one or more of the S-shaped beams
2 further include one or more cutouts for minimizing stress concentrations.
- 1 23. The accelerometer of claim 13, wherein one or more of the S-shaped beams
2 further include one or more cutouts for minimizing webbing formation during the
3 manufacture of the S-shaped beams.
- 1 24. The accelerometer of claim 13, wherein one or more of the S-shaped beams
2 further include a webbing artifact having a hole for preventing the propagation of
3 cracks into the S-shaped beams.

- 1 25. An accelerometer, comprising:
2 a measurement mass for detecting acceleration, including:
3 a housing having a cavity;
4 one or more spring mass assemblies positioned within the cavity,
5 each spring mass assembly including:
6 a support structure;
7 one or more resilient straight beams coupled to the support
8 structure; and
9 a mass coupled to the resilient straight beams; and
10 one or more electrode patterns coupled to the spring mass
11 assembly;
12 a top cap wafer coupled to the measurement mass, including a top
13 capacitor electrode; and
14 a bottom cap wafer coupled to the measurement mass, including a bottom
15 capacitor electrode.
- 1 26. The accelerometer of claim 25, wherein one or more of the spring mass
2 assemblies further include:
3 one or more range-of-motion stops coupled to the support structure for
4 limiting the movement of the mass in the direction of the stops.
- 1 27. The accelerometer of claim 26, wherein one or more of the range-of-motion stops
2 include one or more perforations for minimizing fluid damping.
- 1 28. The accelerometer of claim 26, wherein one or more of the range-of-motion stops
2 are coupled to the side walls of the support structure.
- 1 29. The accelerometer of claim 26, wherein one or more of the range-of-motion stops
2 are coupled to the interior corners of the support structure.

- 1 30. The accelerometer of claim 25, wherein one or more of the straight beams
2 include:
3 a range-of-motion limit stop for limiting movement of the mass in the
4 direction of the stop.
- 1 31. The accelerometer of claim 25, wherein one or more of the straight beams further
2 include:
3 a mass for dampening out resonances of the straight beam.
- 1 32. The accelerometer of claim 25, wherein one or more of the spring mass
2 assemblies further include:
3 one or more soft range-of-motion limit stops for compliantly limiting
4 movement of the mass in the direction of the stops.
- 1 33. The accelerometer of claim 25, wherein one or more of the spring assemblies
2 further include:
3 corner tethers for coupling the corners of the mass to the opposing interior
4 corners of the support structure.
- 1 34. The accelerometer of claim 25, wherein one or more of the resilient folded beams
2 further include one or more cutouts for minimizing stress concentrations.
- 1 35. The accelerometer of claim 25, wherein one or more of the resilient folded beams
2 further include one or more cutouts for minimizing webbing formation during the
3 manufacture of the resilient folded beams.
- 1 36. The accelerometer of claim 25, wherein one or more of the straight beams further
2 include a webbing artifact having a hole for preventing the propagation of cracks.
- 1 37. An accelerometer, comprising:

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2 a measurement mass for detecting acceleration, including:
3 a housing having a cavity;
4 one or more spring mass assemblies positioned within the cavity,
5 each spring mass assembly including:
6 a support structure;
7 one or more resilient beams coupled to the support
8 structure; and
9 a mass coupled to the resilient beams; and
10 one or more electrode patterns coupled to the spring mass
11 assembly;
12 a top cap wafer coupled to the measurement mass, including a top
13 capacitor electrode; and
14 a bottom cap wafer coupled to the measurement mass, including a bottom
15 capacitor electrode;
16 wherein the resilient beams are selected from the group consisting of
17 folded resilient beams, S-shaped beams, and straight beams.

- 1 38. A method of operating an accelerometer having a measurement mass positioned
2 within a housing including top and bottom electrodes positioned between
3 corresponding top and bottom capacitor electrodes, comprising:
4 resiliently coupling the measurement mass to the housing using a resilient
5 folded beam.
- 1 39. The method of claim 38, further including:
2 limiting movement of the measurement mass.
- 1 40. A method of operating an accelerometer having a measurement mass positioned
2 within a housing including top and bottom electrodes positioned between
3 corresponding top and bottom capacitor electrodes, comprising:
4 resiliently coupling the measurement mass to the housing using a resilient

- 5 S-shaped beam.
- 1 41. The method of claim 40, further including:
2 limiting movement of the measurement mass.
- 1 42. A method of operating an accelerometer having a measurement mass positioned
2 within a housing including top and bottom electrodes positioned between
3 corresponding top and bottom capacitor electrodes, comprising:
4 resiliently coupling the measurement mass to the housing using a straight
5 beam.
- 1 43. The method of claim 42, further including:
2 limiting movement of the measurement mass.
- 1 44. A method of preventing crack propagation in a micro-machined structure
2 including a webbing artifact, comprising:
3 providing one or more holes within the webbing artifact.
- 1 45. A method of minimizing backside etching of elements within a micro-machined
2 structure, comprising:
3 providing one or more etch-buffers adjacent to the elements.
- 1 46. A method of improving the dimensional uniformity of elements within a micro-
2 machined structure, comprising:
3 providing one or more etch-buffers adjacent to the elements.
- 1 47. A method of protecting a mass supported within a support structure by one or
2 more springs, comprising:
3 providing one or more soft-contact bumpers for preventing impacts
4 between the mass and the support structure.

- 1 48. A sensor package, comprising:
- 2 (a) a sensor having a mass suspended by a plurality of springs which induce
- 3 mechanical vibrational modes in the sensor, the sensor providing an output
- 4 signal indicative of acceleration detected by the mass;
- 5 (b) a controller coupled to the sensor in a closed-loop configuration, the
- 6 controller in response to the output signal of the sensor providing a digital
- 7 output proportional to the acceleration detected by the sensor, the
- 8 controller in the closed-loop operation having at least one predefined
- 9 frequency band for stable operation relative to the frequency of
- 10 mechanical vibrational modes induced in sensor; and wherein
- 11 the plurality of springs are tuned so that the frequency of the induced
- 12 mechanical vibrational modes remains substantially within at least one
- 13 predetermined frequency band.
- 1 49. The sensor package of claim 48, wherein the sensor is tuned by selecting one of
- 2 (i) shape of the springs, (ii) mass of the springs, (iii) size (dimensions) of the
- 3 springs; and (iv) a combination of at least two of the shape, size and mass of the
- 4 springs.
- 1 50. The sensor package of claim 48, wherein the springs are selected from a group
- 2 consisting of (i) folded beam springs; and (ii) s-shaped springs.
- 1 51. The sensor package of claim 48, wherein the springs are further selected to
- 2 maintain a spring constant within a predetermined range.
- 1 52. The sensor package of claim 51 wherein the spring constant is selected as a
- 2 function of at least one of (i) sensitivity and frequency response of the sensor; (ii)
- 3 dynamics range of the sensor output; and (iii) desired shock tolerance of the
- 4 sensor.

- 1 53. A sensor package, comprising:
- 2 (a) a sensor having a mass suspended from a structure by a plurality of
- 3 springs which induce mechanical vibrational modes in at least one
- 4 direction of movement of the mass, the amplitude of the induced
- 5 mechanical vibrational modes being a function of the mass of the springs;
- 6 (b) a controller coupled to the sensor in a closed loop operation for providing
- 7 a digital output proportional to the acceleration detected by the sensor, the
- 8 controller having a predetermined amplitude threshold level for detecting
- 9 any mechanical vibrational modes of the sensor; and
- 10 wherein the mass of the springs is selected so that the amplitude of the
- 11 mechanical vibrational modes induced in the sensor remains below the
- 12 predetermined amplitude threshold level of the controller.
- 1 54. The sensor package of claim 53, wherein the springs are selected from a group
- 2 consisting of (i) folded beam springs; and (ii) s-shaped springs.
- 1 55. The sensor package of claim 53, wherein the controller further includes at least
- 2 one predefined frequency band for stable operation relative to frequency of a
- 3 mechanical vibrational mode induced by said springs and wherein said springs are
- 4 tuned so that the frequency of the induced mechanical vibrational mode remains
- 5 within the at least one predefined frequency band.
- 1 56. The sensor package of claim 55 wherein the springs are further selected to
- 2 provide a stable operation of the sensor over a selected temperature range.